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MOBILE APPLICATIONS - IMPORTANT ADDITIONAL EDUCATIONAL SOURCE FOR STUDYING CHEMISTRY

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Abstract. The article proposes a brief description of some mobile applications useful both for people who are starting to study chemistry, but also for students. The purpose of the publication is to direct the attention of teaching staff towards this type of tools that can be useful and diversify the student's contact with the discipline of chemistry. There were analyzed 13 mobile applications oriented for different levels of studying chemistry. The opinions expressed by users are mostly positive and express a high degree of satisfaction.

Keywords: *chemistry, smartphone, app, play market.*

Abstract. În articol se propune o scurtă descriere a unor aplicații mobile utile atât pentru persoanele care încep a studia chimia, dar și pentru studenți. Publicația are drept scop de a orienta atenţia cadrelor didactice spre acest tip de instrumente care pot fi utile și diversifică contactul studentului cu disciplina chimia. Au fost analizate 13 aplicații mobile orientate pentru diferite nivele de studiere a chimiei. Opiniile expuse de utilizatori în majoritatea sa sunt pozitive şi exprimă gradul înalt de satisfacției.

Cuvinte cheie: *chimie, smartfon, aplicație, play market.*

1. Introduction

The last 20 years have been marked by essential changes in education, these being caused by the wide use of information technologies, starting with kindergartens and ending with universities. The phenomenon is primarily caused by the essential reduction in the price of equipment and software, which allowed their mass use. Currently, over 95% of the population of the Republic of Moldova and especially the young generation use mobile phones for communication in various forms.

The versatility of smartphones allows operative access to information resources, individual or group communication with other members of the educational process, participation in various types of online tests, etc. At the same time, the possibilities offered by the smartphone can cause addiction to the gadget and cause addictive behavior [1-4]. With all the possible problems caused by excessive use, smartphones make learning activities

more meaningful, transform the learning process into a more attractive form, propose educational information in a more interesting aspect by selecting visual images, improve the quality of the training process , makes the lesson more dynamic. The beneficial aspect of applying these devices in student-centered learning at all stages of education has been noted by a number of researchers [5-7]. At the moment we have at our disposal a multitude of applications that could be used in the teaching-learning-evaluation process, relying on the fact that both the teaching staff and the students have digital competence. In this publication we present possibilities for using smartphones in and outside of chemistry classes, namely applications in the field of general, inorganic, organic and analytical chemistry.

2. Materials and methods

Mobile applications from Google Play Market (Google's app store) served as the research object for studying chemistry (free or paid) proposed to different categories of interested individuals - students, teachers. However, the total number of applications in the field of chemistry proposed by the market could not be determined. Their selection was based on some topics that were of interest to the authors. Another selection criterion was the number of downloads and the average score. The graphic aspect and the textual content were analyzed as additional material in the study of chemistry for different interested groups.

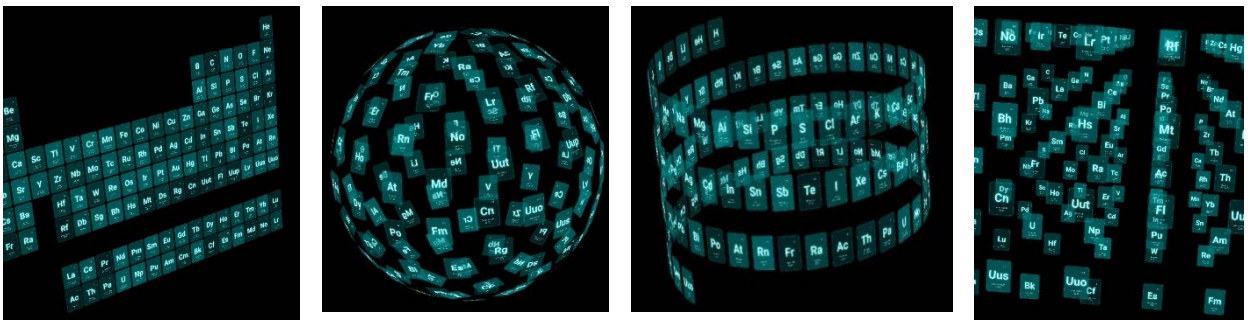
3. Results

We will start the presentation with the Periodic Table of the elements and the useful information presented by it.

Application ***Periodic Table.***

The periodic table of D.I. Mendeleev became the most important milestone in the development of atomic-molecular science. Thanks to her, the existence of chemical elements unknown to science was predicted, their position relative to those known in the table and their properties were established. Later, many elements were discovered and fell into the places that Mendeleev predicted in his table. The periodic system made it possible to form and develop a modern concept of the chemical element, to establish the correlation between the properties of simple and compound substances. The periodic system allowed predicting the existence of some chemical elements not discovered for the moment, describing some chemical properties of the transuranic elements.

This application was developed by Aloask Technologies and it allows us to view the Periodic Table of the elements, a characterization of the element (color, density, melting/boiling point, discoverer). The Periodic Table can be viewed as a table, sphere, helix, grid.



A B C D

Figure 1. The *Periodic Table* of chemical elements presented in different forms (A – table, B – sphere, C – helix, D – grid) [8].

The Pro version of the application contains 2 additional compartments: Test and Advanced features of chemical elements. Since the proposed information is relatively simplistic, the application can be recommended for people who are starting to study chemistry. The rating of application is 4.4 and it has been downloaded more than 10 thousand times [8]. Let's analyze another application that facilitates learning on the topic "Periodic Table", namely *Periodic Table 2020*.

Periodic Table 2024 Pro.

Periodic Table 2024 Pro is very useful both for students and teachers [9]. The application provides extensive information about chemical elements: molar mass, Latin/English name, year of discovery, density, melting/boiling temperature, valence, ionization potential, atomic radius, electronegativity/electroconductivity value, emission spectrum image, specific resistance, type the crystalline network and its parameters, the spread in nature/the human body.

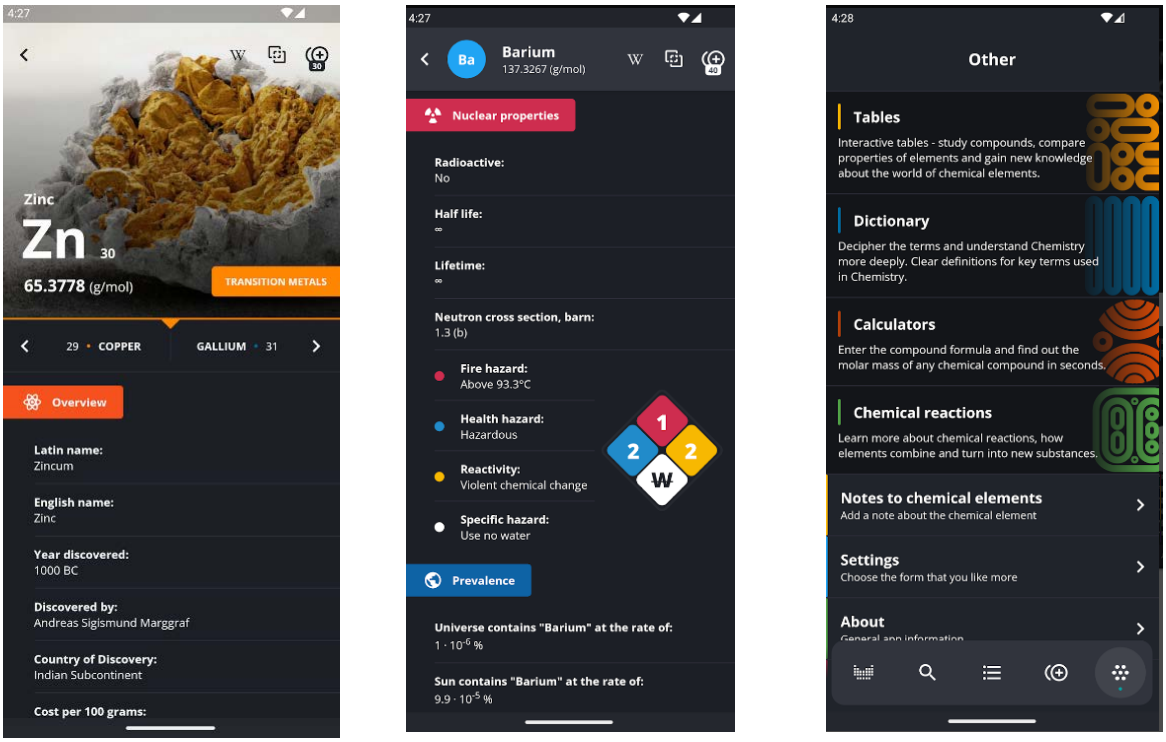


Figure 2. Images from the *Periodic Table 2024 Pro* application [9].

The rating of application is 4.8 and it has been downloaded more than 100 thousand times.

Virtual Orbitals 3D Chemistry. According to modern concepts, the electron has a dual nature and has both the properties of a wave and a particle, therefore, to describe its behavior, one cannot use the usual characteristics, such as speed and trajectory of movement. To describe the state of an electron in an atom, the concepts of quantum mechanics are used - a physical theory that establishes the laws of motion of microparticles. According to quantum mechanical concepts, an electron does not have a definite trajectory of motion and can be located in any part of the space around the nucleus, but with different probabilities. Each orbital corresponds to a region of space of a certain size, shape and orientation, equivalent to the concept of an electron cloud. The *Virtual Orbitals 3D Chemistry* application can be used for the graphic visualization of the electronic orbitals of some atoms. The application allows visualization in 3D of electronic orbitals *s, p, d, f,* p_x, p_y, p_z, d_{xy},

d_{yz}, d_{xz}, d_{x2-y2}, d_{z2} and the spatial electronic structure for a series of atoms – He, Be, C, O, Ne, Mg, Ar, Ca, Ti, Cr, Fe, Zn [10, 11]. The visualization is not static, it is possible to rotate the orbitals in different directions in relation to the *xyz* axes, which greatly simplifies the understanding of the location of the orbitals in space and in relation to each other.

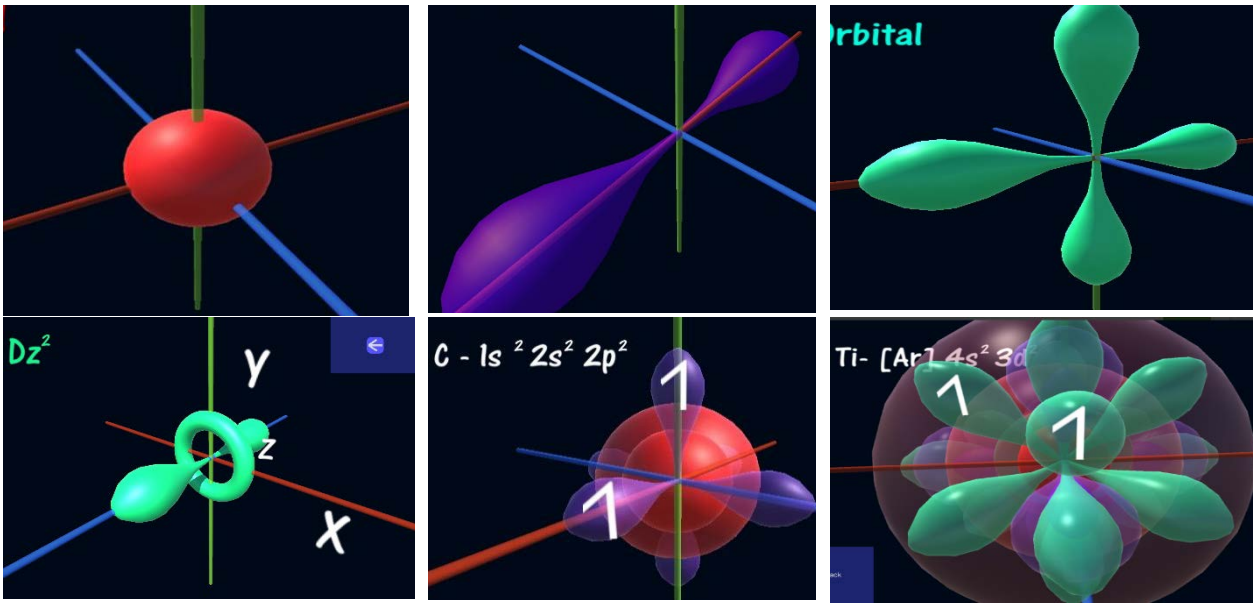


Figure 3. Images from Virtual Orbitals 3D Chemistry [11].

User reviews are mostly positive. The application is appreciated for its simplified use, grading of examples according to difficulty, and the possibility of viewing from different angles. At the same time, some users believe that with all the beautiful aspects, there is also room for improvement - to improve the animation, to offer the possibility of viewing the atomic orbitals on the inner layers for atoms with several electron shells, the visualization of all electrons (not only the valence ones). The rating of application is 4.4 and it has been downloaded more than 100 thousand times.

The following application ***Atom Phys*** allows us to deepen our knowledge in the field of the structure of the atom. The *Atom Phys* application [12] consists of the following compartments: test, modeling of atoms, writing nuclear reactions.

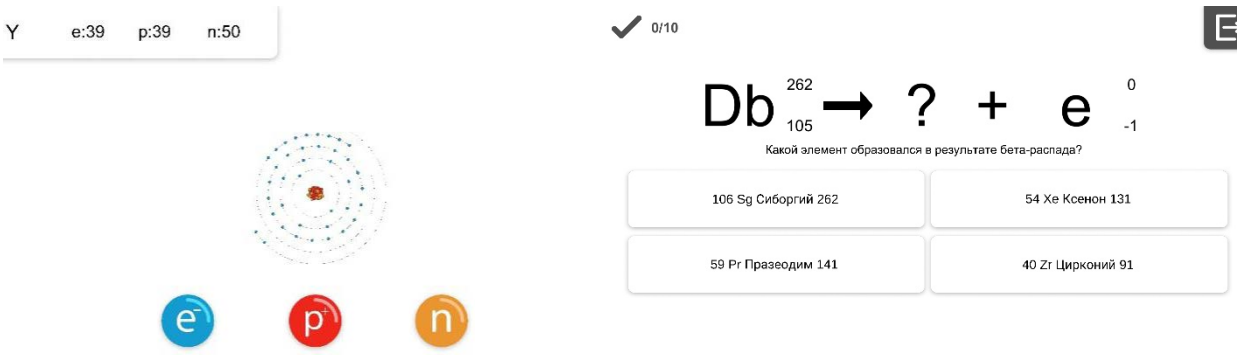


Figure 4. Images from the *Atom Phys* application [12].

The proposed visualization facilitates the study of the topics „Structure of the atom", „Radioactive fission", „Electronic formulas of atoms of chemical elements" by „building" different atoms from protons, neutrons electrons and checking the possibility of the existence

of the given atom; offers the opportunity to recap and test the knowledge of the electronic formulas of the atoms of chemical elements, the realization of α and β type fissions.

Users who have used the application in the fund have left positive opinions. Users are satisfied with the possibility to visualize the "construction" of different atoms, the visualization of the atom structure, the positioning of electrons, etc. The rating of application is 3.9 and it has been downloaded more than 10 thousand times.

Software for drawing structures is an essential tool to visualize and represent chemical substances in a digital format. These programs essentially simplify the creation, manipulation and analysis of the molecular structure of the analyzed compounds. Here's an explanation of their use:

1. Molecular Visualization: Software for drawing structures of molecules allows chemists to generate different representations of chemical compounds. Chemists can input the atoms and bonds of a compound and visualize its structure in different formats: ball-and-stick models, space-filling models, or wireframe models.

2. Drawing and Editing Molecules: The program offers a simplified user interface, which allows drawing and subsequent editing of the obtained structures. The obtained structure can be supplemented with atoms, groups of atoms, functional groups, molecular fragments; the angles between the links can be changed.

3. Molecular Formula Generation: Enter the qualitative and quantitative composition of the compound (empirical formula) and the software generates the molecular formula. This option is extremely useful for compounds with a complex structure.

4. Isomer Generation: The software allows the generation of isomers based on the formulas of the proposed chemical compounds.

5. Structural Analysis: The software allows to determine the molecular mass of substances, to estimate chemical properties and stoichiometric parameters.

One of the programs that facilitates the process of graphical presentation of chemical compounds is *KingDraw*.

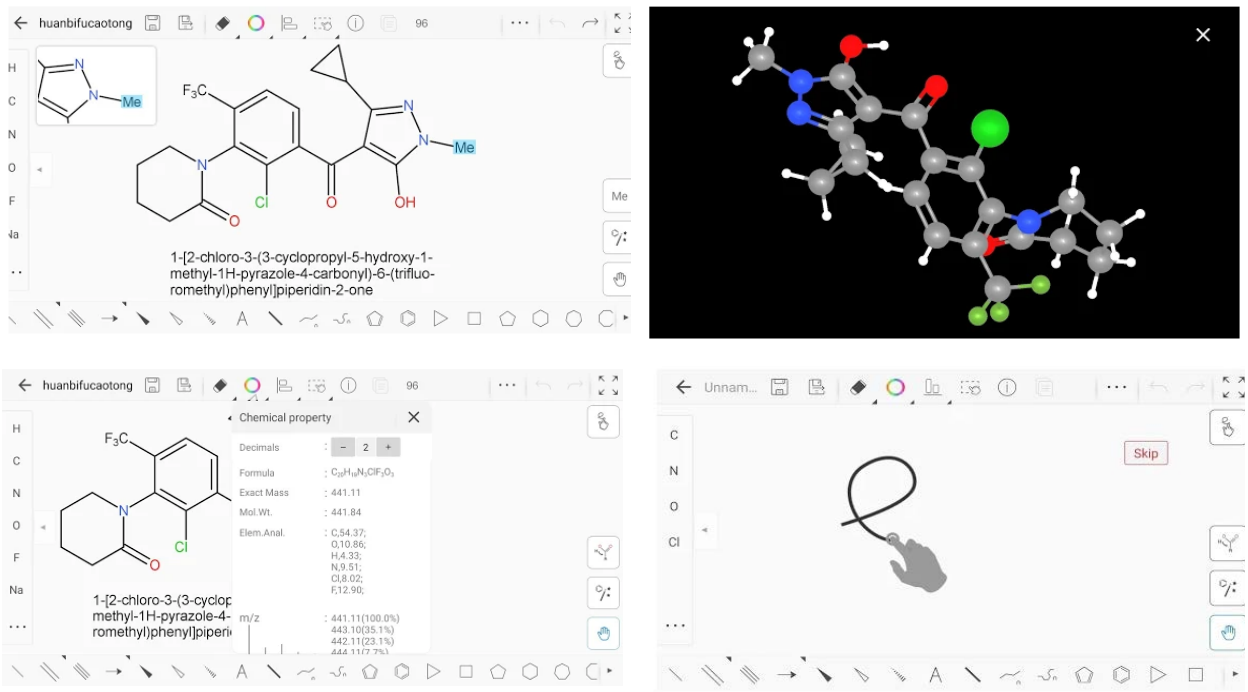


Figure 5. Images from the *KingDraw* application [13].

KingDraw is a chemical drawing editor that allows users to sketch the structure of molecules and the equations of reactions involving organic compounds [13] is possible to visualize the structures in 3D, to name the chemical compounds according to the IUPAC nomenclature, to predict the properties of the drawn compounds. The application has a serious database and can be considered as a semi-professional tool. Possibly the only shortcoming from my point of view – it is a bit difficult to work with small objects on the smartphone screen.

Users who have used the application in the fund have left good opinions. The rating of application is 4.3 and it has been downloaded more than 500 thousand times.

One of the applications that provides useful theoretical information in the field of general, inorganic and organic chemistry is *Chemistry Lab*.

Chemistry Lab. The application has an attractive design and graphics and is divided into 2 sections: General Chemisty and Organic Chemistry [14]. The General Chemisty section consists of Introduction, Atomic Structure, Periodic Table, Ionic Bonding, Covalent Bonding, Chemical Reactions, Moles, Solutions, Acids and Bases, Gases, Thermodynamics, Kinetics, Electrochemistry, Nuclear, Organic, Trivia. Each compartment consists of questions on the corresponding topic with the possibility of choosing the answer from 2 variants. The proposed testing is oriented for an average level of knowledge. In the Organic Chemisty chapter, the mechanism of different chemical reactions with different classes of compounds is explained.

Figure 6. Images from the *Chemistry Lab* application [14].

The majority of users positively appreciated the possibilities of the application: „the application is extremely useful, it is simple, interesting, interactive and is very good for forming interest in chemistry as a discipline". The rating of application is 4.1 and it has been downloaded more than 500 thousand times.

The application is extremely useful, it is simple, interesting, interactive and is very good for forming interest in chemistry as a discipline. Our actions in this area can be simplified with the application *Chemistry Calculator*.

Solution Calculator Lite. The *Solution Calculator Lite* application is a useful tool for: calculating the concentration of the solution (in mM, M, µM, nM, g/ml, g/l) knowing the

volume of the solution and the molar mass of the substance; calculating the volume of the solution with the known initial concentration required to obtain a more diluted solution; calculates the molar masses of chemical elements; provides detailed general information about 118 chemical elements [15].

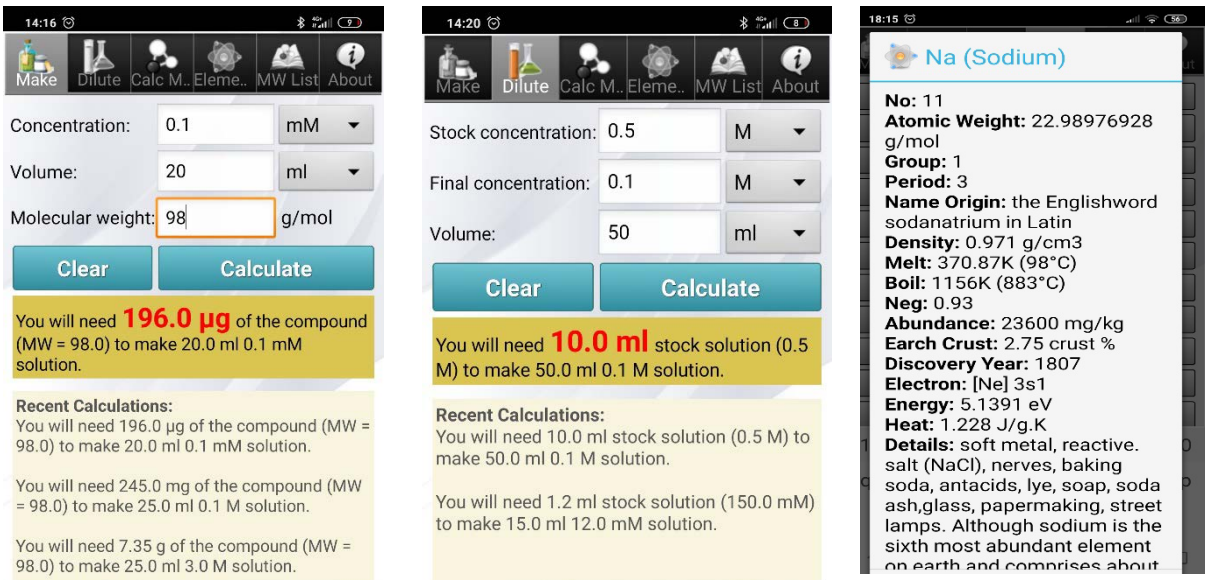


Figure 7. Images from the *Solution Calculator Lite* application [15].

The rating of application is 4.5 and it has been downloaded more than 100 thousand times.

Another extremely useful application, especially for experimental calculations in physical chemistry and colloidal chemistry, is *Chemistry Calculator*, the name of which does not quite optimally express their purpose.

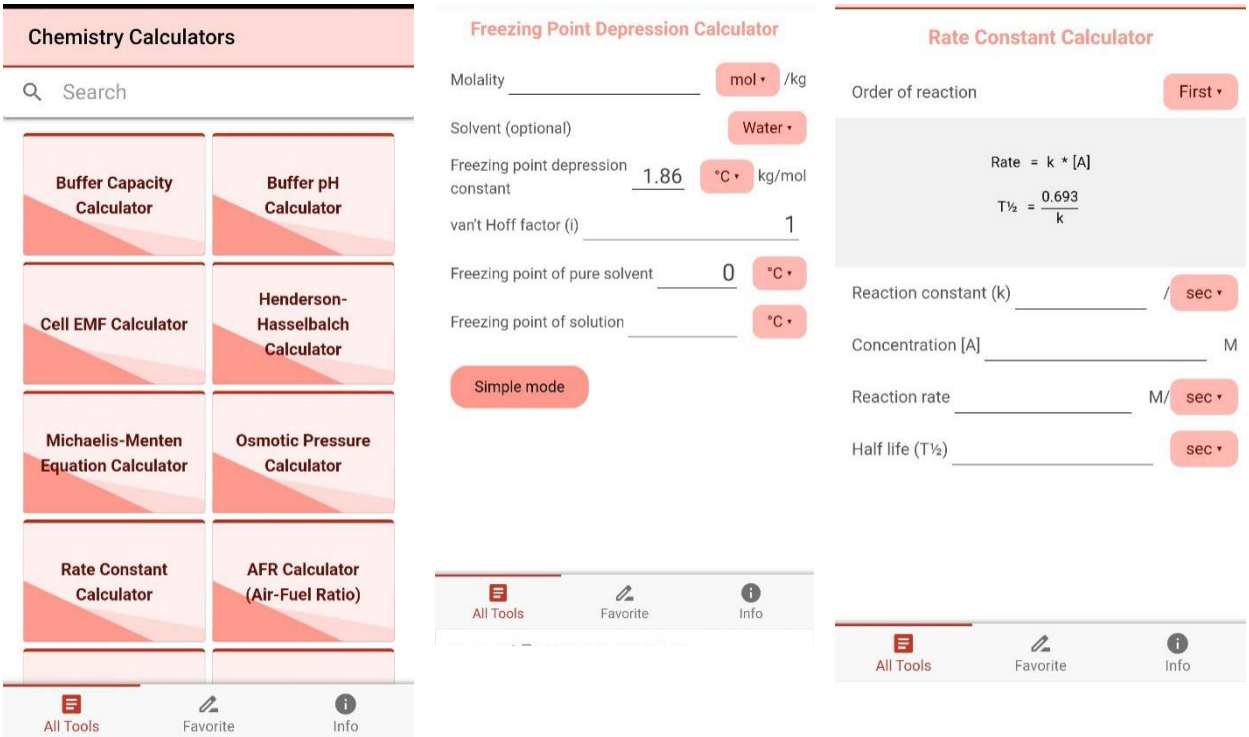


Figure 8. Images from the *Chemistry Calculator* application [16].

Chemistry Calculator. The given application contains an enormous number of tools intended for students and researchers [16]. Having a simplistic design, the application proposes calculations of 75 different parameters. We name only some of them: Buffer Capacity, Buffer pH, Cell EMF, Osmotic Pressure, Rate Constant, Arrhenius Equation, Entropy, Gibbs Free Energy, Surface Tension, etc.

The application essentially simplifies the calculations and is useful for students and researchers related to the discipline of physical chemistry, colloidal chemistry, electrochemistry.

The rating of application is 3.6 and it has been downloaded more than 10 thousand times. The low rating can be explained by the fact that the application was downloaded by random people.

Chemical nomenclature is an important field of chemistry that deals with the naming and classification of chemical substances. The nomenclature of chemical compounds follows certain rules established by international standardization organizations such as the International Union of Pure and Applied Chemistry (IUPAC). These rules establish standardized ways of naming organic and inorganic compounds, as well as other classes of chemicals. The application proposed below in a simplified form allows understanding the principles of naming chemical compounds.

IUPAC Nomenclature Chemistry. The application is very useful for studying organic chemistry and consists of the following sections: Iupac Nomenclature, Organic Reaction Notes, Iupac Practice. The Iupac Nomenclature department proposes, in order to study the way of naming organic compounds according to the IUPAC nomenclature, different variants of knowledge testing on the topic studied. Organic Reaction Notes proposes to describe the methods of obtaining, the chemical properties of organic compounds with the indication of the mechanism of interaction. Iupac Practice proposes a test of the acquired knowledge.

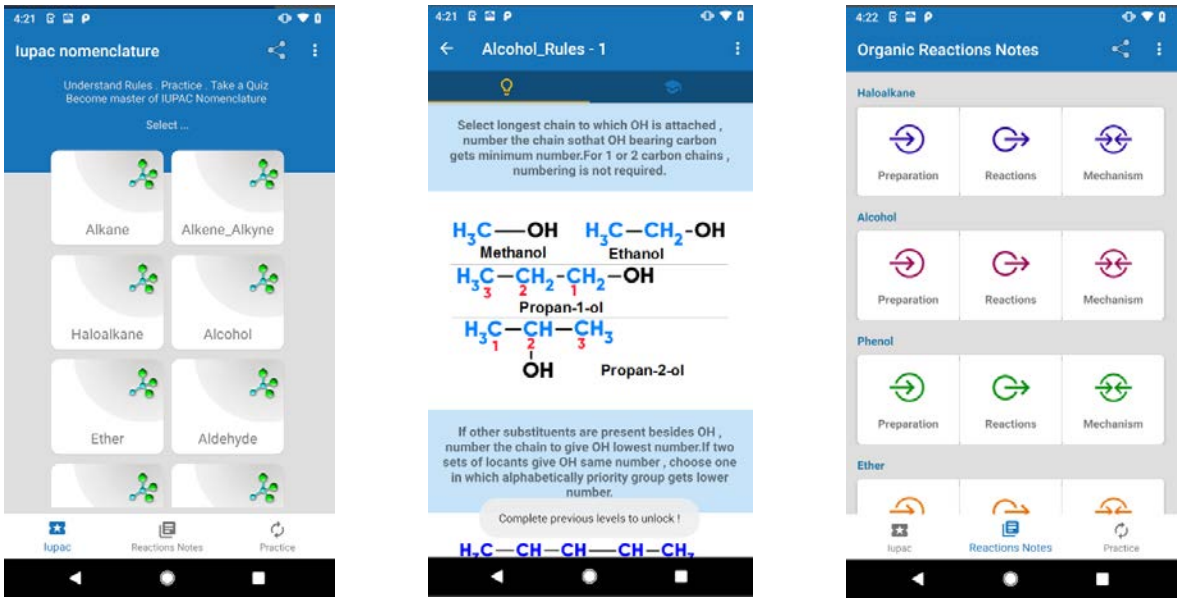


Figure 9. Images from the *IUPAC Nomenclature Chemistry* application [17].

The rating of application is 4.4 and it has been downloaded more than 100 thousand times.

The following three applications are useful in the field of simplified acquisition of theoretical material in different fields - inorganic, organic, instrumental chemistry, etc.

Organic Chemistry Formula Book. The application is useful for X-XII high school students and includes a vast theoretical material from inorganic and organic chemistry and includes the chapters: Periodic Table, mole concept, equivalent atomic and molecular weight, atomic structure, radioactivity, chemical bonding, solid state - unit cell, solid state - impurity and

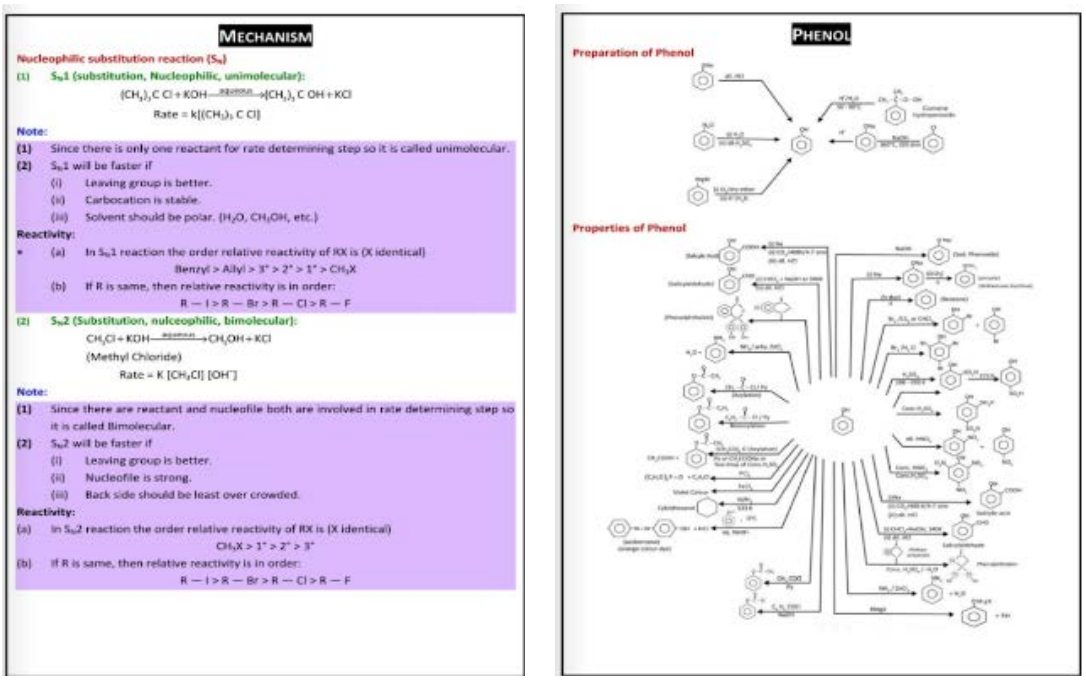


Figure 10. Images from the *Organic Chemistry Formula Book* application [18].

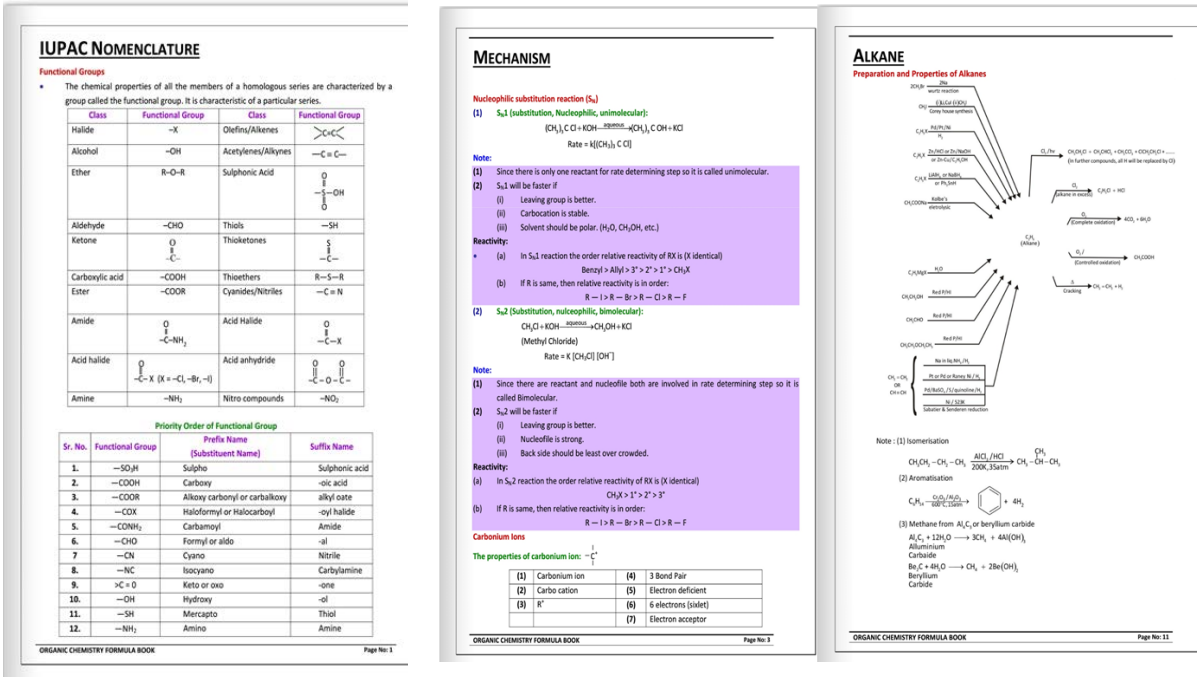


Figure 11. Images from the *Organic Chemistry Formula 2019* application [19].

vacancy, electrochemistry, gas laws, kinetic theory of gases, theory of dilute solution, chemical kinetics, titration, chemical equilibrium, ionic equilibrium and solubility product, thermochemistry, coordination compounds, Werner's theory, hydrogen, alkali metals, boron, carbon, nitrogen, phosphorus, oxygen, sulfur, halogen, hydrochloric acid, nobel gases, d-bock transition elements, f-block, important minerals, qualitative analysis, IUPAC nomenclature,

electronic effects and application, isomerism, alkane, alkene, alkyne, benzene, haloalkane or alkyl halide, haloarene or aryl halide, alcohol, ether, phenol, nitrobenzene, amine, aniline, aldehyde and ketone, carboxylic acid, general formula of organic compounds, IUPAC name of some organic compounds, etc. [18].

The rating of application is 4.0 and it has been downloaded more than 50 thousand times.

Organic Chemistry Formula 2019. The application is useful for recapitulating the matter of organic chemistry and offers information in the following sections: IUPAC nomenclature, mechanisms of chemical reactions, qualitative and quantitative analysis, chemical properties and methods of obtaining alkanes, alkenes, alkynes, alcohols, phenol ethers, aldehydes and ketones, acids carboxylic and their derivatives, nitro compounds, amines, benzene, polymers [19].

The rating of application is 4.2 and it has been downloaded more than 30 thousand times.

Electro Chemistry. The *Electro Chemistry* application is a manual application, in which the theoretical material related in more than 50 topics in the field of electrochemistry is presented in an accessible form. The information is presented in a clear and concise form [20].

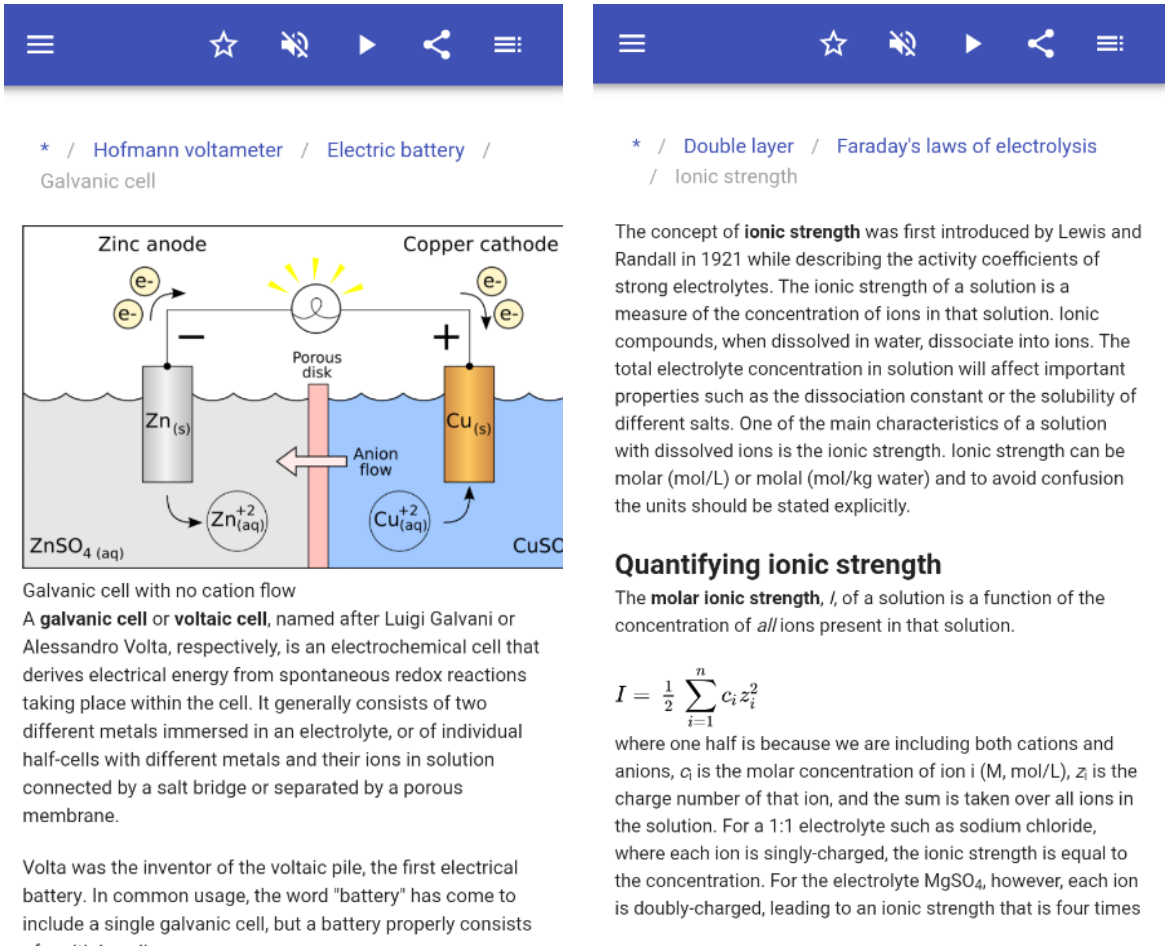


Figure 12. Images from the *Electrochemistry* application [20].

The application is useful for students studying electrochemistry. The rating of application is 4.5 and it has been downloaded more than 50 thousand times.

Analytical Chemistry. Application *Analytical Chemistry* is made up of 35 sections, which describe in detail the theoretical information in the most essential fields of analytical

chemistry – aqueous solutions and chemical equilibrium, the gravimetric method of analysis, acid-base titration, standard electrode potentials, molecular absorption spectrometry, gas chromatography, high-performance liquid chromatography, etc. [21].

The application is extremely useful to chemical students specializing in the field of analytical chemistry. The information presented allows the recapitulation of the theoretical and practical aspects of the studied field.

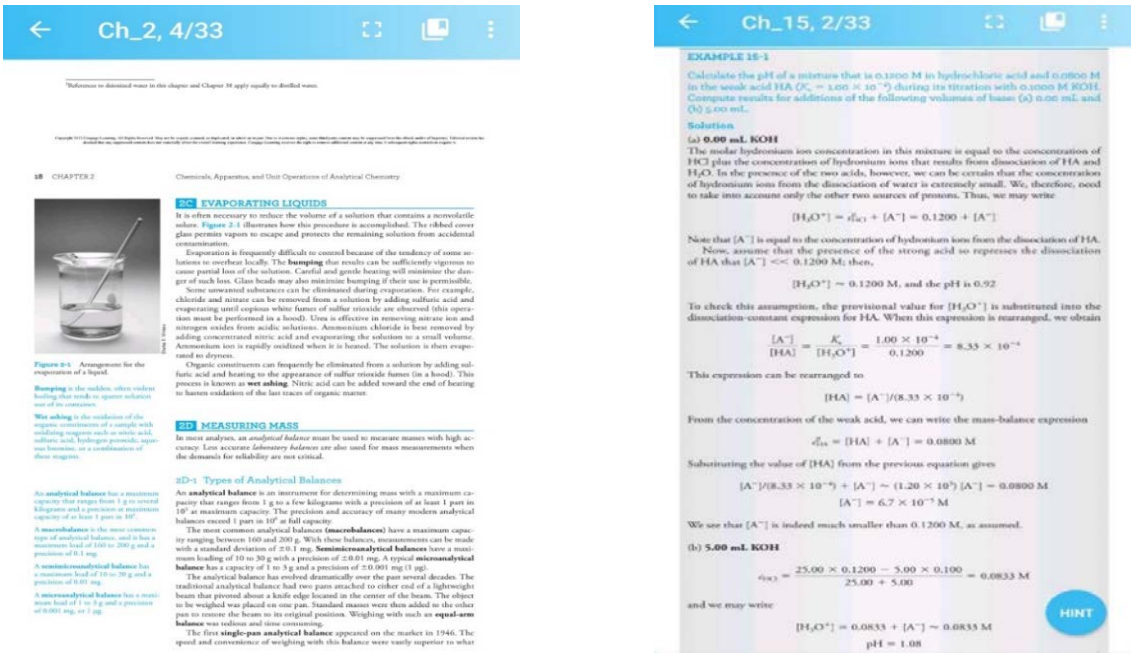


Figure 13. Images from the *Analytical Chemistry* application [21].

The application presents important theoretical support for students studying analytical chemistry and instrumental methods of analysis. The rating of application is 4.3 and it has been downloaded more than 20 thousand times.

3. Discussion

Mobile applications have become increasingly important in the process of studying chemistry due to their multiple benefits. Here are some reasons why using mobile apps is important in studying chemistry: accessibility - mobile apps enable access to information and learning resources anywhere and anytime, making it easier for students to supplement or strengthen their chemistry knowledge; interactivity - many mobile apps offer interactive lessons, games and simulations that help students reinforce their knowledge through hands-on activities; customization - mobile applications can be customized to suit the individual needs of students, providing them with a learning environment adapted to their own pace; time efficiency - by using mobile apps, students can save time and effort when searching for information or answers to their chemistry related questions; various resources - in addition to traditional lessons and materials, mobile applications offer a wide range of additional resources such as video tutorials, practice tests and topic guides. The application of mobile applications in the process of studying chemistry brings a diverse set of advantages that facilitate the acquisition of knowledge and their consolidation through innovative and interactive methods.

4. Conclusion

It is indisputable that the development of the Internet, information and communication technology has affected almost every aspect of teaching and learning. New technologies open up additional opportunities and motivate for training, giving teachers, students and pupils the opportunity to improve themselves. One of the possible additional means of training - mobile applications - can be recommended by teachers as an additional source of learning.

Conflicts of Interest: The authors declare no conflict of interest.

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